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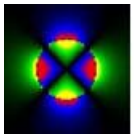
Magnet Division Procedure

Procedure: SMD-AGS-3001

Revision: B



Superconducting
Magnet Division

AGS Snake Magnet Coil Insulating & Winding

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Revision History

Rev A: Initial Release 7/10/03
Rev. B: Changes per ECN #MG1278

1 Scope:

This procedure describes the initial fabrication of Inner & Outer Helical Coil Assemblies for the AGS Snake magnet (refer to SMD-AGS-3002 for the final fabrication steps). The operations include insulating the tubes, stabilizing and potting leads, and coil winding. Also included are all appropriate inspections and testing.

2 Applicable Documents:

RHIC-MAG-Q-1000	Procedure for Control of Measurement Test Equipment
RHIC-MAG-Q-1004	Discrepancy Reporting Procedure
RHIC-MAG-R-7227	Electrical Resistance Measurements
RHIC-MAG-R-7228	Coil Inductance & Q Measurements
RHIC-MAG-R-7242	Hypot Testing
RHIC-MAG-R-8853	Hypot Testing – Helical Coil Insulation Assembly
BNL Dwg. 22010003	Inner & Outer Coil Insulating Assembly
BNL Dwg. 22010004	Inner & Outer Coil Winding & Curing Assembly

3. Requirements:

3.1 Material & Equipment

Black Felt Tip Pen	BNL Stock No. S-23757
Latex Gloves	BNL Stock No. K-62856 (ex large)
Tie Wrap	BNL Stock No. A-59829
VELCRO Straps	
Brush	BNL Stock No. I-56400
Non-conductive Black Marker	BNL Stock No. S-23757

High Efficiency Particulate Air (HEPA) filter equipped vacuum cleaner.
Dial Indicator
Heat Gun
Insulated gloves
Orangewood sticks
Scale
Solder pot
Soldering Iron
Teflon lined steel clamps
Test Rack ETS-001
Ultra Sonic Welder (Sonics & Materials, Inc. Model H-520 (Generator), Model CV53 (Head) 500 W output)
Vented Hood
Web Straps

3.2 Safety Precautions:

3.2.1 To avoid the possibility of static build-up and discharge during coil winding operation, grounding must be installed. Attach a ground wire to the coil support tube. Attach incoming lead for coil block being wound to ground. After all the coil blocks are wound remove the ground wires.

3.2.2 Operators shall wear:

- Insulated gloves when handling heated coil assembly or soldering operation.
- Latex or PVC gloves while handling epoxies.
- Latex gloves while handling acetone, ethanol.

NOTE

Latex gloves only give marginal protection to most solvents used and should only be considered as protection from incidental contact/exposure. If the glove is contaminated, it should be removed and a new glove put on.

3.2.3 Operators shall wear safety glasses with side shields, or goggles while using epoxy.

3.2.4 Some of these electrical test procedures have specific safety requirements. The technicians performing these specific tests shall rigorously follow all the safety requirements listed as well as those prescribed by the BNL ES&H standard.

3.2.5 The technicians shall be instructed by their cognizant technical supervisor in the operation of the required test equipment and these electrical testing procedures. They shall be familiar with the latest revision of the applicable documents referenced in section 2. In addition, some of these tests require the technician to have special training. A list of qualified personnel shall be maintained with the training coordinator.

3.2.6 Hypot testing poses a Class “C” electrocution hazard. At least two properly trained technicians must be present to perform this testing. When testing, a trained technician shall be stationed at any point the item under test is accessible to unauthorized people, and barriers shall be set up. Signs shall be posted reading “DANGER HIGH VOLTAGE” and warning lights shall be turned on.

3.2.7 Specific steps of this procedure contain electrical and mechanical assembly operations that impact the environment. Prior to performing these steps, personnel shall complete the applicable facility specific environmental training.

4 Procedure:

4.1 Preparation for Coil Insulating

4.1.1 Visually inspect coil tube for any damage or machining burrs. If necessary deburr any sharp edges with 240 grit sandpaper or file.

4.1.2 Break sharp edges left from machining on the lead entrance opening of each lead end Coil block, approximately 0.015 +0.015/-.000" radius; use 240 grit sand paper. (See Dwg.12011004).

4.1.3 Clean tube thoroughly using a vacuum, removing all chips, and wipe out slots with alcohol.

4.2 Insulating Coil Slots

4.2.1 The coil support tube insulation is done in four different ways consistent with the four distinct regions of each slot to be insulated. A schematic showing the four regions is given in Figure 1. The start and stop points of each region are based on the ability of the Kapton pieces to conform to the required slot curvature; exact locations are left to the discretion of the technician during application.

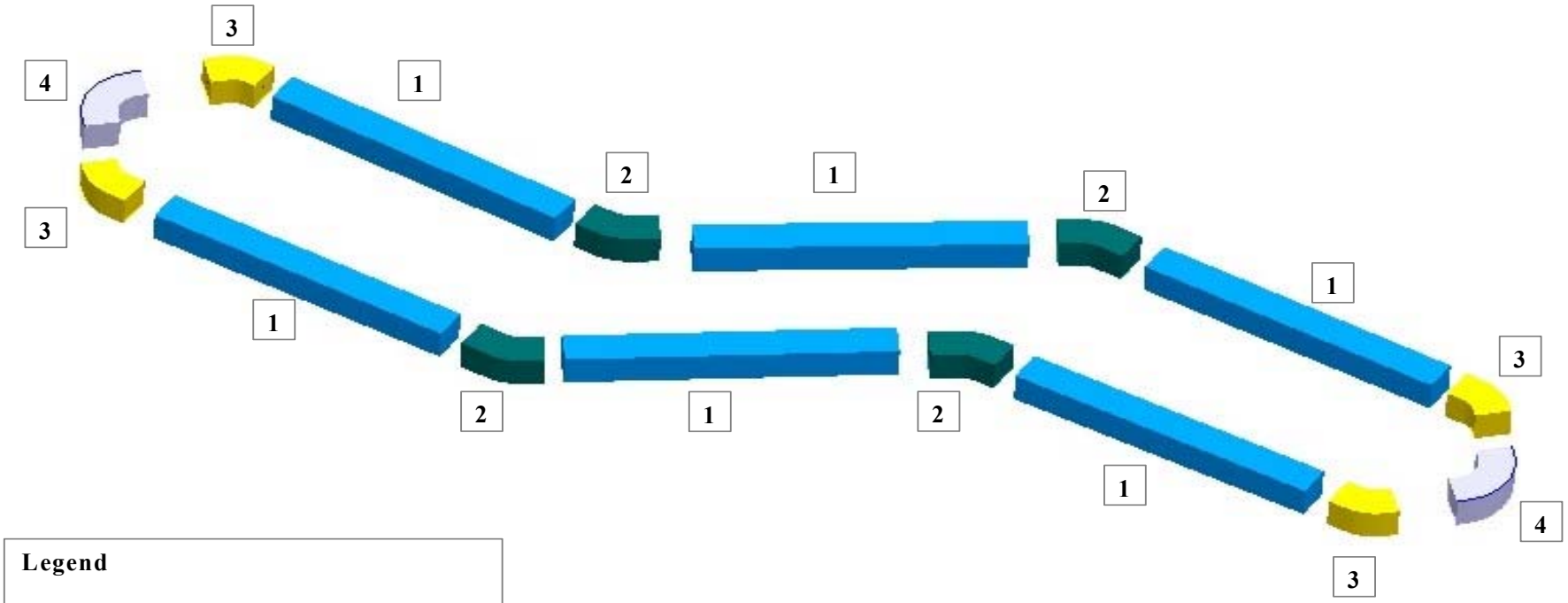
4.2.2 For the **"straight"** regions of the two helices (region 1), apply "L" caps to the slot's two lower inside corners and to the two upper outside edges in accordance with the assembly drawing. The bottom of the slot uses adhesive-backed Kapton, but the walls are insulated using transfer tape and non-adhesive Kapton.

4.2.3 For the **"transition"** regions between the two helices (Region 2) and for the **"small radius"** regions in the coil ends (Region 3), apply vertical strips of 0.375-wide adhesive-backed Kapton. When applying, overlap the previous piece by 50%, and overlap onto the coil OD by a minimum of .015 inches.

4.2.4 For the **"large radius"** regions in the coil ends (Region 4), apply vertical strips of 0.75-wide adhesive-backed Kapton. When applying, overlap the previous piece by 50%, and overlap onto the coil OD by a minimum of .015 inches.

NOTE

Insure Kapton film is pressed firmly into the lower corners, and then along the contour of the slot.



Legend

1	Straight Regions
2	Helix Transition Regions
3	Ends, Small Radius Regions
4	Ends, Large Radius Regions

Note:

A .002 thick NOMEX liner will be used throughout, placed between the coil conductors and the Kapton, to prevent bonding. At the butt joints, .001 Kapton will be used to seal the joints.

Figure 1 - Kapton Insulation Scheme

4.2.5 Cover gaps between Kapton "L" pieces in the bottom and along the sides of the slot using Kapton film [P/Ns 1201081-43, and 22010037 & 39 (IC) or 22010038 & 40 (OC)].

NOTE

Insure Kapton film is pressed firmly along the contour of the slot.

4.2.6 Repeat paragraphs 4.2.2 thru 4.2.5 for all remaining coil block slots.

4.3 Hypot Testing

4.3.1 Perform Hypot Testing of Assembly as specified in Procedure RHIC-MAG-R-8853.

4.4 Nomex Protectors

4.4.1 Nomex protectors are used to prevent epoxy from bonding to the Kapton on the bottom and walls of the slots. Such bonding can cause Kapton rupture during cooldown.

4.4.2 Fabricate Nomex Protectors per drawing.

4.4.3 Apply transfer tape on bottom and vertical walls of slots.

4.4.4 Install protectors. Protectors should be trimmed to butt end to end.

4.5 Spooled Cable

4.5.1 If not previously done, respool cable from master spool(s) onto smaller spools not exceeding 2300 feet each. Refer to drawing 22010004 for the cable lengths required for winding each block. The cable for several blocks may be placed on one spool. Label respooled cable spools with the coil(s) and block(s) it will be used with.

4.5.2 If spooled cable resistance measurements were not performed during cable handling, then obtain measurements per Appendix 2.

4.6 Preparation for Coil Winding

4.6.1 Visually inspect insulated coil support tube for any damage to Kapton insulation. Vacuum clean assembly. Repeat Hypot test if any regions are suspect.

4.6.2 Enter wire and cable identification numbers for each coil block in table on production traveler.

4.7 Incoming ["Start"] Lead Stabilizers

4.7.1 Cut 49" lengths of cable (P/N 12000030, surplus stock) as stabilizers.

NOTE

Inner & Outer Coils each require 10 incoming stabilizers.

4.7.2 Remove insulation from all stabilizers. Solder coat ("tin") the stabilizers using solder pot filled with tin/silver solder (P/N 12010923). Clean stabilizers with alcohol, removing all flux residues.

NOTE

Ensure unused solder is recycled or disposed of properly.

4.7.3 Obtain spool of cable for coil block to be wound. Slide 2" length of 0.063" diameter shrink tubing (P/N 12040126-03) over end of spooled cable. Insure shrink tubing is slid far enough back so it is not affected by heat from the following soldering operation.

4.7.4 Remove the Kapton insulation from the first 50" of the spooled cable.

NOTE

Exercise care when cutting insulation to avoid damaging superconductor.

4.7.5 Apply flux to the bare spooled cable and "tin" with tin /silver solder. Apply flux to the pre-tinned stabilizer and tinned cable end. Clamp together and solder. Clean with alcohol.

NOTE

Ensure unused solder is recycled or disposed of properly

4.7.6 Wrap stabilized lead with Kapton tape (P/N 12010181-35) using half overlap wrap. Wrap must start at the end and should continue approximately 0.5" beyond the stabilized lead.

4.7.7 Slide the 2" length of 0.063" diameter shrink tubing forward on the cable spool until it butts against the stabilized lead and then shrink.

4.7.8 Install 0.125" diameter shrink tubing over the entire length of the stabilized lead. `Overlap the .063" shrink tubing as shown on drawing. While heating, stretch tube slightly to help get a tight shrink onto the stabilized lead, if required.

4.7.9 Repeat steps 4.7.3 to 4.7.8 for all the remaining cable spools to be used. If cable for multiple coil blocks is on a single spool, this step will need to be repeated again as cable is used.

4.8 Temporary End Spacers

4.8.1 Prepare the outermost slot (largest end radius) for winding before the others. Work progressively inward to the next slot as the previous coil block is completely wound.

4.8.2 Install temporary Teflon Cable Spacers in the Lead End & Non-Lead End of the coil slot prior to winding. Secure spacers to outside wall of slot using transfer tape. See drawing table for part numbers and locations. The spacers should extend between the radii of the two machined reliefs on the outer wall.

4.9 Substrate (Pre-Preg) Installation

NOTE

Check drawing 12011019 (IC) or 12011020 (OC) for required substrate part numbers for every layer installed. Required part numbers are dependent upon layer and coil block.

4.9.1 Cut the required substrate curved end pieces for the coil block and layer to be wound. Sheets of transfer tape must be present on both sides of substrate before cutting.

4.9.2 Remove protective backing from transfer tape (P/N 12011353) on the fiberglass side of the curved end pieces. Install curved end pieces in bottom of slot, fiberglass side down. Apply pressure to insure contact. Trim if necessary.

4.9.3 In the same way install straight sections of substrate into the "straight" helices, fiberglass side down. Ends of substrate must butt up to the curved end pieces within 0.04 inches. Firmly press to set substrate in place.

4.10 Nomex Lead-In Protector

4.10.1 Install Nomex lead-in protector 22010036 as shown on drawing 22010004. Attach with transfer tape.

4.10.2 Form the stabilized lead into the lead slot as shown drawing detail "Start of Winding".

NOTE

Minimum bend radius for leads is 0.3 inches.

4.10.3 Bond the start point of the unstabilized part of the cable into the coil block with 5-minute epoxy. See drawing for location. Bond to bottom and side of slot as required.

4.10.4 Form pieces of "Green Putty" on both sides of the lead wire using forming tool, and allow to harden. Trim and remove excess putty. Clean/vacuum thoroughly.

4.10.5 Put second Nomex lead protector cover piece [P/N. 22010058-xx (IC) or 22010059-xx (OC)] in place and mark where relief must be cut for lead to enter bottom of coil slot; cut relief as shown on drawing. Install lead protector over cured putty, attaching with transfer tape.

4.11 Coil Winding

4.11.1 Starting with the outermost slot (largest end radius), wind the first layer of the coil block. Check drawing for the required number of turns and layers.

4.11.2 Upon completion of turn 12 in this layer, wrap the cable (half overlap) with Kapton tape (P/N 12010181-35) at transition point (transition point is where the cable rises up to the next higher layer in the coil; see dwg. for transition locations).

4.11.3 Fully seat the turns into the substrate by using the ultrasonic welder. The on-time dwell at each location should not exceed 3 seconds to prevent liquefying the epoxy in the substrate, but the time and pressure must be sufficient to **soften the epoxy, push and hold down the cables, and allow the epoxy to cool so that the cables do not spring back.**

4.11.4 Repeat 4.9.1, 4.9.3, and, 4.11.1 through 4.11.3, installing substrate, winding cable, and seating turns until the coil block has the required number of layers.

4.11.5 Perform steps 4.9.1 through 4.9.3 again to install substrate over top layer of coil block. Remove temporary Teflon end spacers.

4.11.6 Quench studies are to be conducted on this magnet. To perform these studies, diagnostic spot heaters and quench detection voltage taps are to be added. Refer to Appendix 3 for locations.

4.11.7 Install spot heaters and V-taps in accordance with Appendix 3.

4.11.8 Trim outgoing cable to a length of 50" past the outgoing lead exit point. See dwg. for exit points.

4.11.9 Install quench heater strips on the top layer of the coil block's **center helix** only.

4.11.10 Install press plates for center helix only (P/N 22010034-xx).

4.11.11 Bend up quench heater ends 90 degrees to allow next straight section press plates to be installed.

4.11.12 Install the appropriate **end helix** press plates [P/Ns 22010013 & 0035 (IC) or 22010014 & 0043 (OC)]. See drawing 22010004 for part identification and location. Cut and trim press plates as necessary for butt joints, leaving room for quench heater strips to protrude in gap.

NOTE

Gap should not exceed .03 inches to ensure proper support of superconductor

4.11.13 Fold down heater strip ends at 90° onto end helix press plates. One side of each end will overlap the coil tube OD. Trim this side of ends to fit within slot. Refer to drawing.

4.11.14 Install **non-lead end** press plate.

4.11.15 Strip 0.50 inches of insulation from the quench heater lead wire. Solder lead wires to the copper end on two (of four) heater strips at the non-lead end, one in each helix. Dress quench heater lead wires into end helix press plates and non-lead end press plates. Trim wire to correct length to join with other heater strip, and remove 0.50 inches of insulation. Anchor wires in grooves using cyanoacrylate.

4.11.16 Repeat steps 4.8.1 through 4.11.15 for all remaining coil blocks.

4.11.17 Clamp **non-lead end** press plates using Teflon-lined steel clamps. Do not over-tighten.

4.11.18 Locate Teflon-lined steel clamps every 4" along coil length of both "straight section" helices.

NOTE

These clamps must be installed whenever the coil is not being worked on. If the lead press plates will not be modified immediately, they must be installed temporarily so that clamps can be applied to the lead end also.

4.11.19 Temporarily secure incoming and outgoing leads to coil support tube with tape. Minimum bend radius for lead is 0.3 inches.

4.12 Lead End Press Plate Modification

4.12.1 Temporarily place **lead end** press plates into their respective coil slots. Starting with the innermost coil block, mark the locations on the lead end press plate where the channels in coil tube must cross

4.12.2 Inspect lead wire crossover locations in tube channel for high-spots. Correct or modify as necessary to insure flat placement of lead wires. Label incoming and outgoing leads for future reference.

NOTE

Operations on G10 material that can produce dust (machining, cutting, grinding, sanding) require proper safety practices. Eyes and skin protection and HEPA filter vacuum required. **Refer questions to ES&H Coordinator/FS Representative.**

4.12.3 For each press plate, cut slots into the surface so that the lead channels from the coil tube are continuous across the press plate. Check that the bottoms of the slots in the plate are smooth and provide the same depth as the slots in the coil tube.

4.12.4 Repeat 4.12.1 through 4.12.3 for each press plate at the lead end.

4.13 Outgoing ["Finish"] Lead Stabilizers

4.13.1 Cut 49" lengths of cable (P/N 12000030, surplus stock) as stabilizers.

NOTE

Inner & Outer Coils each require 10 outgoing stabilizers.

4.13.2 Remove insulation from stabilizers and "tin" using solder pot. Clean stabilizers with alcohol.

NOTE

Ensure unused solder is recycled or disposed of properly

4.13.3 Install 2.0" piece of 0.063" shrink tubing (P/N 12040126-03) over the outgoing coil lead. Do not shrink at this time.

4.13.4 Remove the insulation from all the coil block outgoing leads to within 1.0" of the lead exit point. See drawing 22010003.

NOTE

Exercise extreme care when removing insulation to avoid damaging superconductor.

4.13.5 Clean all outgoing coil leads with Scotch-Brite pad and wipe clean with alcohol.

4.13.6 Using solder & paste (P/N 12010923-02 /12010069), "tin" all outgoing coil block leads.

4.13.7 Apply flux to pre-tinned outgoing lead and to stabilizer. Clamp the entire length of the stabilizer parallel to the outgoing lead.

4.13.8 Solder stabilizer and lead together. Clean stabilized lead with alcohol to remove excess flux.

NOTE

Ensure unused solder is recycled or disposed of properly

4.13.9 Wrap stabilized lead with Kapton tape (P/N 12010181-35). Start the wrap at the lead exit point and wrap using 50% overlap until end is reached.

4.13.10 Slide 0.063" shrink tubing (from step 4.13.3) to butt against stabilizer, and shrink.

4.13.11 Install one layer of 0.125" diameter shrink tubing (p/n 12040126-01) for the entire length and shrink. Overlap existing 0.063 shrink tubing as shown on drawing.

4.13.12 Repeat steps 4.13.7 through 4.13.11 to stabilize remaining leads.

4.14 Dressing Leads

4.14.1 Slide a length of Teflon tubing over lead wires. Label “Start” and “Finish” leads.

4.14.2 Inspect all coil blocks. Insure press plates are in proper location, all wires are below press plates, and all lead wires are correctly labeled. Inspect quench heater leads for proper seating in slots, and quench heater strip for proper routing up between straight press plate sections.

4.14.3 Teflon-lined steel clamps should be closely spaced (minimal gap), and bolt torques should be uniform.

CAUTION

Uneven torque and /or spacing of clamps can cause wires to bulge, which will result in unsupported wires. Wires protruding from under press plates may be pinched between plate and tube, resulting in shorts and /or permanent damage.

4.15 Lead Wire Channels

4.15.1 Fabricate Nomex lead channel liners, P/N 12011187. Trim each channel to length as required.

4.15.2 Place channel liners in lead wire slots and note void areas to be filled underneath. Remove liners and fill void between bottom of lead slot and underside of channel liner using FT epoxy (blue). Install liners into the wet epoxy to bond them in place.

4.16 Lead Wire Sleeves

4.16.1 Cut Nomex sleeve (12050280) to length (full length of lead channel plus 0.125") and slide over incoming lead, outgoing lead, and quench heater leads. Ensure that wires will lie side-by-side inside tube and do not become crossed or twisted. Locate wires in order shown on drawing detail.

4.16.2 Locate the lead wire group into its channel. Check that wires lie flat by pressing down on group.

4.16.3 Cover exposed sections of wire with NOMEX patch (.015” thick).

NOTE

Minimum bend radius of 0.3” for lead wires.

4.16.4 Bond the lead wires to the channels using cyanoacrylate (“Superglue” or equivalent). Fill all around lead wires inside the channel liner using FT epoxy.

4.16.5 After epoxy has cured, bend edges of channel liners inward over wires.

4.16.6 Place into position any quench heater wires that must cross the lead channel. Securely replace clamps over coil end.

4.16.7 Cut two 1" pieces of red shrink tubing (12011368-01) and slide over incoming lead. Position one piece 1.5" from end of tube, and the other 1.0" from the end of the incoming lead. Shrink in place.

4.16.8 Locate two wire labels (12011367) on each wire (Start & Finish), correctly labeling the identity of the coil block so all labels can be seen after coil is wrapped.

NOTE

Every lead must have 2 wire labels. The start lead for each block must also be identified with red shrink tubing.

4.16.9 Repeat steps 4.16.1 through 4.16.8 for remaining leads.

4.17 Electrical Tests

4.17.1 Perform electrical testing per Appendix 1.

5 Quality Assurance Provisions

5.1.1 The Quality Assurance provisions of this procedure require that the technician shall be responsible for performing all assembly operations in compliance with the procedural instructions contained herein and the recording of the results on the production traveler.

5.1.2 The technician is responsible for notifying the technical supervisor and/or the cognizant engineer of any discrepancies occurring during the performance of this procedure. All discrepancies shall be identified and reported in accordance with RHIC-MAG-Q-1004.

5.1.3 Measuring and test equipment used for this procedure shall contain a valid calibration label in accordance with RHIC-MAG-Q-1000.

6 Preparation for delivery:

N/A

Appendix 1 - Electrical Testing

NOTE

Pay particular attention to safety requirements included in individual electrical test procedures.

1. Measure coil temperature and the RLQ for each coil block. Perform test in accordance with RHIC-MAG-R-7227 & RHIC-MAG-R-7228.

2. Measure the leakage current of each coil block in accordance with RHIC-MAG-R-7242. Normal Hypot voltage is 1.0Kv. *NOTE: If Coil has previously been cold tested, this hypot test shall be performed at only 500 volts*.

   Maximum leakage current is 50µA.

3. Measure the leakage current of each Quench Protection Heater Circuit in accordance with RHIC-MAG-R-7242. Hypot voltage is 1.0Kv.

   Maximum leakage current is 50µA.

4. Cognizant Electrical Engineer to review test data and sign-off "OK to proceed"

Appendix 2 - Cable Spool Measurements

- Measure the Resistance and Temperature of the spooled cable for each coil block.

- Cut a 36" sample from each wire spool. Tag each sample with cable identification number, block number, date and initials. Example of tagged cable shall read:

    - Block # : HCD 5011
    - Cable ID: BNL-14-N-002-A
    - Date: : 3/01/99
    - Initial : RJ

- Route cable samples to the cable test group prior to coil winding. Verify each spool was measured for resistance, weighed, and 36" sample taken.

Appendix 3
Locations of Diagnostic Spot Heaters and Voltage Taps